The advantages of using reduced coating diameter optical fibers (200µm) in ADSS cables for deployment in FTTx networks

Paul van Zyl
CBI Electric Telecom Cables
Brits, South Africa
+27-12-381-1498 · pvzyl@cbitele.com

Ian Davis
Corning Limited
Ewloe, Flintshire CH5 3XD, United Kingdom
+44-1244-525-386 · davisim@corning.com

Abstract

Smaller, lighter All-dielectric Self-supporting (ADSS) cables are enabled by reduced diameter optical fiber to allow faster FTTx installation.

Conventional ADSS optical fiber cables incorporate fairly large buffer tubes and make use of standard ITU-T G.652.D fibers of 245µm diameter. The maximum fiber count of conventional ADSS cables in South Africa is 144 fibers and such cables are substantial in diameter and weight. Smaller, lighter cables can be achieved through the use of ITU-T G.657.A1 and G.652.D compliant, bend-tolerant fiber featuring a reduced fiber diameter of 200µm.

The operational advantages of the smaller, lighter cables include faster deployment with significantly fewer returns due to failures caused by inappropriate storage of slack lengths of buffer tubes in tight bends within closures. In addition, 200µm fiber enables the generation of an ADSS cable with total fiber count increased from 144 to 288, enabling much more network capacity.

This paper will focus on ADSS cables incorporating up to 288 fibers having a span capability of approximately 60 m for deployment in FTTx networks.

Keywords: ADSS; Reduced diameter; Bend-tolerant; Smaller, Lighter cables; Faster deployment; Strain free window.

1. Introduction

The largest FTTx deployment on the African continent is currently taking place in South Africa. Initially, FTTx deployment is being concentrated in major metropolitan regions where telecommunications operators are competing in a fierce “fiber land-grab”, targeting areas where anticipated connection rates are high and where cables can be installed quickly to deliver the largest possible network footprint. The incumbent operator set a target during 2015 for 1 million homes connected by 2018 [1]. Achieving this target is challenged by alternative providers achieving significant take-up in prime suburbs through fast build-out and aggressive pricing.

In order to accelerate build-out the incumbent operator’s initial policy of mainly underground deployment (to safeguard their investment from potential damage, either intentional or incidental) was revised to include more aerial deployments. Due to the availability of existing overhead infrastructure (telephone and street lighting poles), ADSS fiber optic cables are in huge demand as this installation method is the fastest and can allow an operator to more quickly pass all the homes in a targeted region, achieve high connection rates through being the first available provider and thereby establish an early revenue stream.

Use of 200µm fiber enables an improvement of more than x2 in the fiber density of the 288-fiber cable compared to a 144-fiber design using conventional ITU-T G.652.D compliant fiber as shown in figure 1. The bend-tolerance of the G.657.A1 200µm fiber also enables smaller hardware and equipment in the network (as the fiber may be installed in tighter turns) and upgrades to protocols relying on longer wavelength transmission (where the bend resistance of the fiber is even more critical to maintaining low-loss).

Testing of the 288-fiber ADSS cable is presented. The cable performed equivalently to the 144 fiber conventional cable and demonstrated enhanced bend properties. Excellent tensile testing demonstrates a wide strain-free window for the cable, essential for maintaining operation in high winds over large temperature variations. Temperature cycling and other standard mechanical tests for the cable such as crush, impact, torsion and bend delivered results well within standards requirements and operator specification.

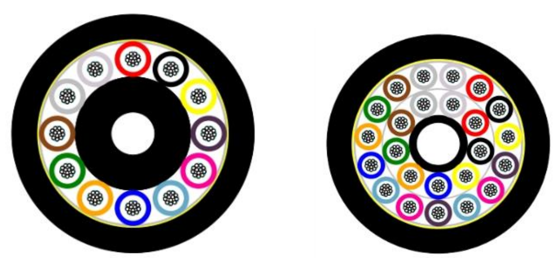

Figure 1. ADSS Cables – 144 Fiber cable incorporating conventional ITU-T G.652.D fibers (left), and 288 Fiber cable incorporating G.657.A1 200µm fibers (right).

2. Reduced Coating Diameter Optical Fiber Technology

As major telecoms operators embark on large-scale deployments of fiber in the access network, maximizing both the volume of fiber installed and the fiber density in the cable is important. The former consideration addresses the need to maximize total data carrying capacity, important as developments such as High Density and Virtual Reality Video, 5G and Internet of Things absorb more capacity. The latter consideration addresses using the often limited space in the existing duct network most efficiently, deferring the need to install costly new duct infrastructure into the future. Note that, although overhead ADSS cables are not necessarily space-constrained, the limitation on size and weight has an impact on pole or tower loading and is an analogous driver towards higher fiber density in these cables.

Despite significant evolution since the first commercially viable product emerged in the early 1980s, geometrical dimensions of optical fibers have remained largely the same; a 9µm core and

125µm cladding traps the light using the principle of internal reflection while a 245µm diameter coating protects the glass from mechanical damage. The coating also protects the light-carrying capability of the glass by shielding it from external stresses that otherwise could cause small deviations in the axis of the core leading to loss of optical power through microbending.

To enable tighter packing of fiber in the cable, a new generation of single-mode fibers has been introduced with coating diameter reduced from 245µm to 200µm while still retaining the same 125µm glass diameter of conventional single-mode fibers. The unchanged glass diameter is important as it ensures that established industry equipment and procedures for splicing and connectorization are unchanged, eliminating a potential barrier to wide-scale adoption. The smaller coating diameter delivers an overall fiber cross-sectional area reduction of ~30% which together with other down-sized elements of the cable that are enabled by 200µm (e.g. buffer tube), leads to cable designs with much higher fiber density. This benefit can be exploited by either designing smaller cables with a particular fiber count, or by designing cables of similar size with much higher fiber count. Figure 1 illustrates cables that combine these advantages.

Reduced cushioning of external stresses by the thinner coating could lead to more microbend losses for a 200µm fiber in a densely packed cable, so an ITU-T Recommendation G.657 compliant glass design is typically employed, as this tends to deliver both superior macrobend performance and enhanced microbend resistance to the product. The fiber employed in this study was of the G.657.A1 category, with nominal mode-field diameter of 9.2µm, well matched for compatibility with legacy fiber in the network. Enhanced macrobending performance can be exploited by allowing smaller, more visually unobtrusive closures to be introduced to the network.

3. Critical ADSS Cable Design Considerations

3.1 Installation Conditions

For the purpose of tensile testing the customer specification requires cable tension under normal and worst case conditions to be calculated for each cable size using equations 1, 2 and 3 [2]. Calculations are carried out based on a span distance of 60 m, installed cable sag of 0.5 m, and a worst case wind loading of 125 km/h (723 Pa).

For the 288-fiber cable Every-Day-Stress (T_1) was calculated at 1.64 kN, and a worst case load (T) of 2.4 kN. This compares favourably with the conventionally designed 144-fiber cable that was calculated at 1.9 kN and 2.7 kN respectively for Every-Day-Stress (T_1) and worst case load (T).

Figure 2 shows Every-Day-Stress (T_1) against cable sag for 144-fiber(200µm), 288-fiber(200µm) and 144-fiber conventional cables. Figure 3 shows the worst case load (due to 125 km/h wind) and cable deflection (blow-out) based on the initial sag without wind, from 0.4 m to 0.6 m for the same cables.

It is clearly evident that the smaller and lighter compactly designed cables incorporating 200µm fibers can be installed at reduced sag levels with acceptable levels of cable tension, providing improved ground clearance for the cable. It is easier and faster to install smaller and lighter cables. It also makes it easier to co-locate such cables on existing poles/towers over larger, heavier conventionally designed cables.

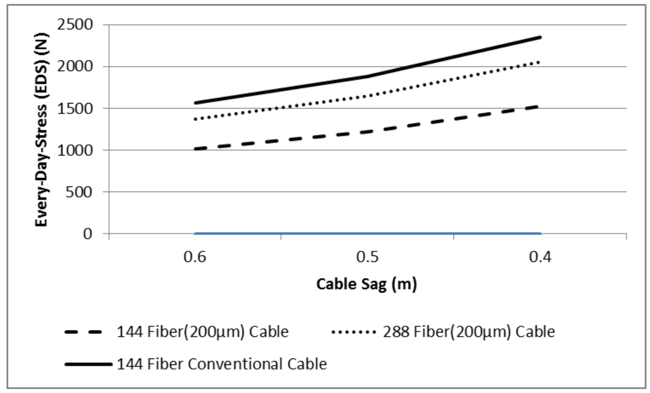

Figure 2. Every-Day-Stress vs Sag

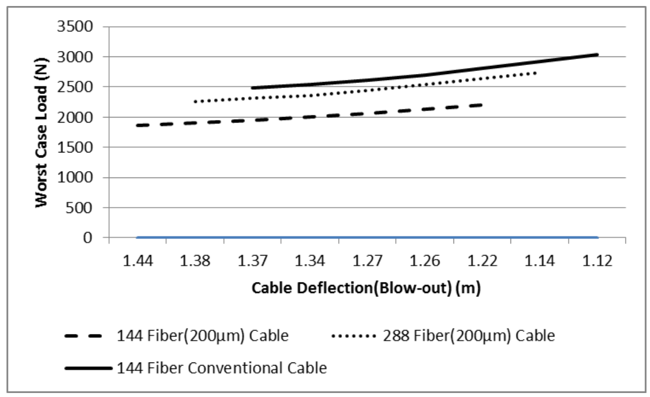

Figure 3. Worst Case Load vs Deflection (Blow-out)

$$T_1 = \frac{WgL^2}{8S} \tag{1}$$

Where:
T_1 = Every-Day-Stress (EDS) (N)
W= Cable weight (kg/km)
g = Gravitational acceleration (9.81 m/s^2)
L = Span distance (m)
S = Cable sag (m)

$$W_1 = \sqrt{W^2 + \left(\frac{FPD}{g}\right)^2} \tag{2}$$

$$T^3 + \left[\frac{W^2 g^2 L^2 Ea - T_1 - Eak\,(t_1 - t)}{24T_1^2}\right] T^2 = \frac{W_1^2 g^2 L^2 Ea}{24} \tag{3}$$

Where:
W_1 = Resultant force (N)
T = Resultant tension due to wind load (N)
E = Net Young's modulus of load bearing elements (MPa)
a = Cross-sectional area of load bearing elements (mm^2)
k = Net Coefficient of linear expansion of load bearing elements (per degree Celsius)

t_1 = Temperature at which T_1 is calculated (55° C)
t = Temperature at which T is calculated (-6° C)
P = Wind pressure (Pa)
D = Projected area per meter of cable (m)
F = Shape factor (0.6 for circular cable)

3.2 Strain Free Window

ADSS cables are designed to de-couple fiber stresses from other cable materials. It is necessary for optical fibers to have sufficient strain free window as ADSS cables are self-supporting and continuously exposed to tensile stresses when in service. Installation conditions such as span distance, maximum sag, wind loads and temperature variations form an integral part of the specification and are reflected in qualification tests. Due to the use of 245µm diameter optical fibers and having to meet specified requirements, buffer tube sizes cannot be very small. Reduced coating diameter optical fibers made it possible to reduce the buffer tube size by 24%. For buffer tubes containing 12 fibers, fill ratios of 34% and 48% are calculated for conventional and 200µm fiber cables respectively, by using equation 4.

$$(d^2 \div D^2) \times 100 \tag{4}$$

Where:
d = Fiber bundle diameter (mm)
D = Buffer tube inner diameter (mm)

4. Construction of ADSS Cables Using Reduced Coating Diameter Optical Fibers

A new range of ADSS cables incorporating ITU-T G.657.A1 and G.652.D compliant, bend-tolerant 200µm diameter fibers was designed. Physical properties of the cables compared to conventional cables are shown in figures 4 and 5.

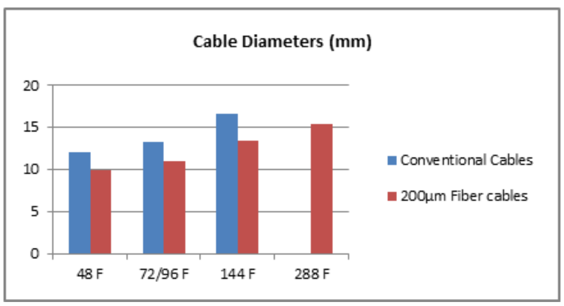

Figure 4. Cable Diameter Comparison

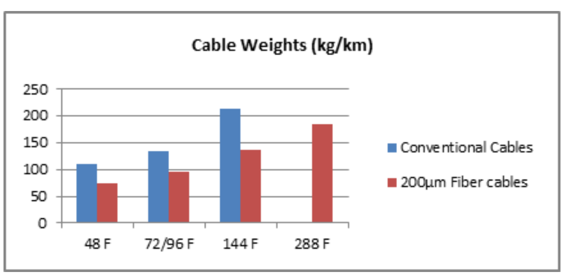

Figure 5. Cable Weight Comparison

5. Testing of a 288-Fiber ADSS Cable Using 200µm Fibers

Cable qualification testing was carried out to determine compliance with customer specifications and the requirements of IEC 60794-3-20. In addition, tests were also carried out to ensure certain company internal requirements are met (i.e. cable / hardware compatibility).

(The above mentioned requirements are the same as for conventional cables).

5.1 Mechanical Tests

5.1.1 Tensile Test

Figure 6 shows the tensile performance of the cable. Fiber strain for fibers in the center and outer layer buffer tubes were measured separately. Fiber strain in both buffer tube layers started at approximately 2 kN. The cable produced zero fiber strain at Every-Day-Stress (T_1 = 1.64 kN), and less than 0.2 % fiber strain at worst case load (T = 2.4 kN) which met customer requirements.

(IEC 60794-3-20 requires fiber strain at maximum allowed tension (MAT) not to exceed 0.2% [3]).

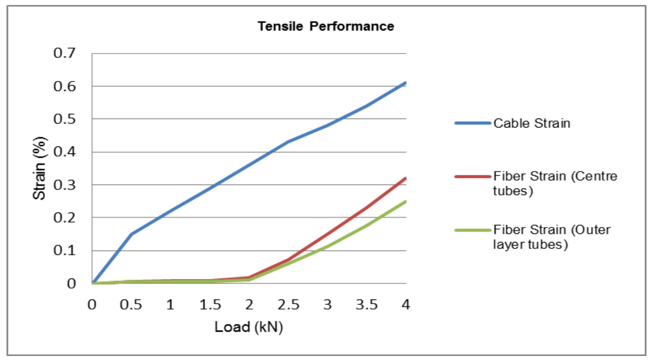

Figure 6. Cable Tensile Performance

5.1.2 Tube Kink Test

Tube kink tests are carried out in accordance with IEC 60794-1-23 (Method G7). The purpose of this test is to determine the ability of tubes containing optical fibers to withstand mechanical stresses encountered during cable installation and splicing. Since the 288-fiber cable features smaller, thinner tubes to achieve the higher packing density, maintaining sufficient resistance to kinking under stress was important to establish. A typical minimum value for the tube loop diameter is 60 mm, since this aligns with the minimum specified bend diameter in the ITU-T Recommendation G.652 for standard single-mode fiber, and also represents a minimum practical value of coiled tube loops within a joint or other connectivity plant. The minimum loop diameter is calculated based on the movable distance during the test.

In addition to the stated requirements it was decided to carry out tests to simulate seasonal atmospheric conditions (0° C, 25° C and 50° C) at a loop diameter less than the recommended 60 mm. The rationale here was to verify the more severe conditions encountered in an FTTx installation environment.

The results are shown in Table 1. A “Pass” result indicates that no kinking of the tube was visible.

Table 1. Tube Kink Test Results

Test Temperature (° C)	Moving distance (L) *	Calculated minimum tube loop diameter	Result
23 (Ambient)	60 mm	60 mm	Pass
0	100 mm	48 mm	Pass
25	100 mm	48 mm	Pass
50	100 mm	48 mm	Pass

* As defined in IEC 60794-1-23, Method G7

5.1.3 General Mechanical Tests

General mechanical test results are shown in Table 2. The cable passed all the tests.

Table 2. Mechanical Test Results

Test Method (IEC 60794-1-21)	**Test Conditions**	**Worst Case (under load)**	**Load released**
Crush (Method E3A)	1500 N	0.04 dB	0.03 dB
Impact (Method E4)	2 J ; 25 mm Striking surface radius	0.02 dB	0.02 dB
Torsion (Method E7)	1 m ; 180°	0.03 dB	0.02 dB
Mandrel Bend (Method E11A)	12 d	0.04 dB	0.01 dB
Repeated Bend (Method E6)	90° ; 50 cycles ; 20 d	0.05 dB	0.04 dB

Pass criteria: 1) Under visual examination without magnification, there shall be no damage to the sheath and cable elements. 2) There shall be no change in attenuation at 1550 nm after the test (No change is considered to be ≤ ± 0.05 dB).

5.2 Environmental Test

The cable was subjected to 4 cycles where the minimum temperature was –10° C and the maximum +70° C. The total duration of the test was 96 hours. The temperature performance was well within the requirements of not exceeding 0.1 dB/km during the test and having no change in attenuation after the test at 1310 nm and 1550 nm. The results are presented in figures 7 and 8.

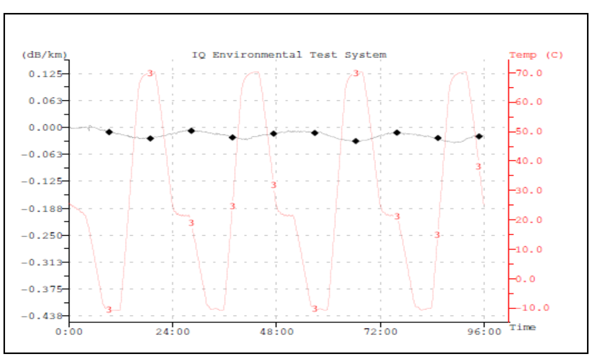

Figure 7. Temperature Cycling at 1310 nm

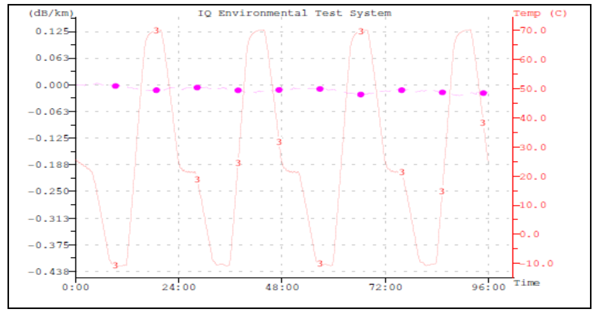

Figure 8. Temperature Cycling at 1550 nm

5.3 Hardware Compatibility Test

The purpose of the hardware compatibility test is to verify there is a certain safety margin when the cable and clamp combination is exposed to extreme temperatures and tensile loads. This is an in-house test also known as the "hot-box" test, see Figure 9.

During the test a 15 m length of cable is attached to the capstan wheel of a tensile machine. At the other end the recommended galvanized steel spiral wire dead-end clamp is applied and fixed to an anchor. The clamped area of the cable is conditioned at 60° C for 2 hours in a "hot-box". A tensile load of 3 times the worst case loading (as calculated using equations 1, 2 and 3) is then applied for 10 minutes.

The load in this case was 7.2 kN and there was no slippage between the clamp and cable during and after the test. After removal of the clamp the cable did not show signs of permanent damage or deformation.

The cable and clamp combination therefore met the requirements.

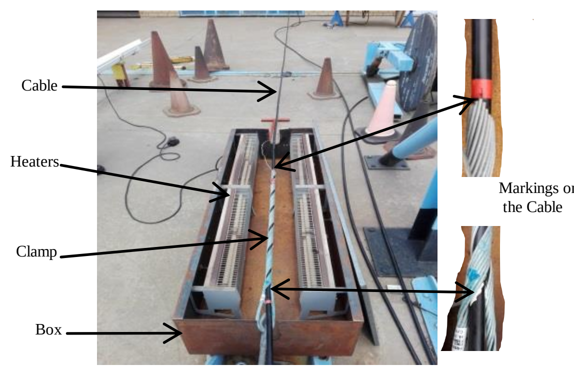

Figure 9. Test Arrangement ("Hot-box")

6. Installation Performance

6.1 Typical Installation Environment

Access and FTTx networks require feeder cables from the central office that generally incorporate high fiber counts. Although the incumbent operator tries to utilize existing underground infrastructure for feeder cables where possible, competitors often opt for overhead installation as they do not have access to underground infrastructure. The increased fiber density of 200µm fiber cables now provides an opportunity for more fiber to be installed using the same effort (In a situation where two 144-fiber conventional cables is planned for installation, now only one 288-fiber 200µm fiber cable is required, therefore installation effort is halved). In addition, overhead installation is much faster and reduces costs.

A large portion of distribution cables are typically installed on wooden telephone poles carrying existing copper infrastructure that often runs between houses in residential areas as shown in Figure 10. This is a challenging environment as property owners are not always available to allow access to the property to facilitate the installation and in some cases disallow the cutting back and clearing of garden trees that would provide the installer with a more straightforward routing of the cable. In addition to these difficulties, the skill levels of installation teams are not always as high as would be desired and so the final installation may not always be completed perfectly.

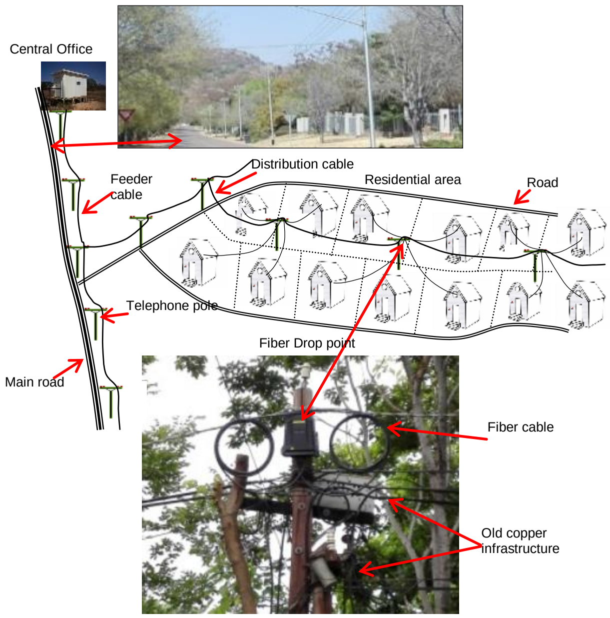

Figure 10. Typical Network Scenario

6.2 Connectivity Plant

Procedures regarding fiber and cable handling in conjunction with splice closures, slack storage boxes, cabinets, pedestals, hardware, etc., require careful consideration to ensure successful "first-time" installation. It becomes problematic and costly when technicians have to return after initial installation to remedy problems. It is a requirement for connectivity plant in FTTx networks to be as small as possible due to space constraints and aesthetics. Bend tolerant fibers, and smaller, light-weight buffer tubes and cables, are therefore required to match connectivity plant.

6.2.1 Connectivity and Storing Enclosures

Telecommunication operators required a certain length of buffer tubes to be stored inside closures (i.e. 1.8 m). The process of storing buffer tubes in such closures involves a manual process whereby the tubes are carefully removed from the cable and finally coiled into a circular bundle that is stored in a closure as shown in Figures 11 and 12. This process requires proper procedures and skilled technicians to ensure damage does not occur to the buffer tubes and fibers.

Unfortunately due to difficult working conditions and the presence of some less-skilled technicians, procedures are not always followed precisely. Also, some closures have limited space and depending on design, the resultant inner coil diameter is not always properly controlled, as illustrated in the picture on the right in Figure 12.

There are also cases where bare fibers are accidently routed incorrectly in splice trays resulting in coil diameters significantly less than 60 mm (Figure 13). This situation increases the possibility of encountering macro bending losses for conventional G.652.D fibers.

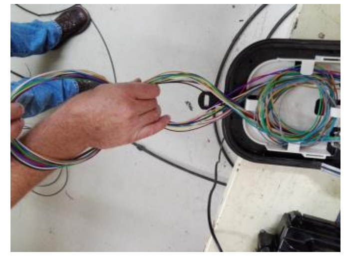

Figure 11. Storing Buffer Tubes in a Closure

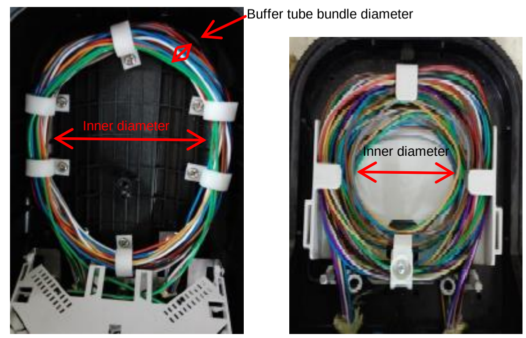

Figure 12. Inner Coil Diameter

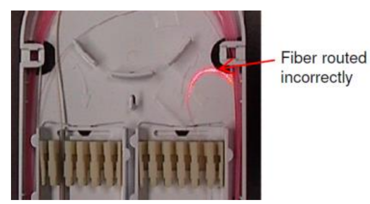

Figure 13. Bare fibers in a Splice Tray

6.2.2 Advantages of Reduced Size Fibers and Cables

The use of 200µm fibers resulted in a 24 % buffer tube size reduction compared to conventional cables. Due to the size reduction of buffer tubes in 200µm fiber cables the resultant tube bundle diameter to be stored in a closure also decreases significantly. Table 3 shows the size relationship between tube bundles of conventional cables and cables containing 200µm fibers for various cable sizes.

Handling capabilities are enhanced due to the following:

(a) The smaller buffer tube bundle for a particular cable size is easier to control and store in connectivity plant without complications.

(b) Higher fiber count cables can be used without having to use larger connectivity plant.

(c) Bend-tolerant fibers can handle accidentally introduced bends of small radii therefore mitigating attenuation losses due to poorly controlled installation conditions.

Table 3. Buffer Tube Bundle Sizes

	Cable size (Number of fibers)				
	48	72	96	144	288
Number of buffer tubes	4	6	8	12	24
# Number of buffer tubes per bundle	12	18	24	36	72
## Bundle diameter (mm) Conventional cables	10.4	12.5	15.0	17.5	-
## Bundle diameter (mm) 200µm fiber cables	7.9	9.5	11.4	13.3	19.3

Coiled 3 times to store approximately 1.8 m.

Assuming a symmetrical and tightly packed bundle

7. Conclusions

A new range of ADSS cables was presented incorporating 200µm ITU-T Recommendation G.657.A1 compliant, bend-tolerant fibers. The cable design demonstrates enhanced overall performance for suitable deployment in an FTTx environment. Faster, more efficient overhead installation is enabled with improved ground clearance compared to conventional designs. The enhanced macro bend performance of the optical fibers and smaller buffer tubes allows bending to smaller radii therefore allowing reduced size connectivity plant. Installation is optimized due to cables and hardware being reduced in size compared to conventional cables. Lower skilled installation teams may be utilized as cables are more "forgiving" regarding errors resulting in tighter bending of the fibers in the buffer tubes. The bend tolerant property of the fibers also provides a future upgrade path for higher speed transmission relying on longer wavelength operation. Qualification testing demonstrated compliance with industry and customer standards (same requirements as for conventional cables).

8. Acknowledgments

Special thanks to Christo Theron for the tests he carried out, and to Wynand Frost for his contributions regarding installation performance.

9. References

[1] G. van Zyl, ed., *"Fibre coming to 12 000 Bryanston homes"*, fin24tech. fin24 news, (September, 2015).

[2] H. Hughes, ed., *Telecommunications Cables Design, Manufacture and Installation*, 1st ed., Wiley, Chichester UK, p. 210 (1997).

[3] IEC 60794-3-20, *Optical fibre cables – Part 3-20: Outdoor cables – Family specification for self-supporting aerial telecommunication cables*, IEC, 3rd ed., (2016)

10. Authors

Paul van Zyl

pvzyl@cbitele.com

Paul van Zyl's tertiary studies earned him a diploma in electrical engineering after which he joined Siemens Cables, South Africa in 1983. He worked alongside experienced cable design engineers contracted from Siemens, Neustadt (Germany) and was appointed Cable Design Engineer in 1985. In 1986 he was appointed Cable Development Engineer at ATC (Pty) Ltd (now CBI Electric Telecom Cables) where they manufactured mainly telecommunication cables including fiber optics. His first major project at ATC was to investigate the pros and cons of different optical fiber cable designs to determine the company's future direction in this regard. In 1996 he was appointed as Technical Manager.

van Zyl is currently also the chairman of the South African mirror committee for IEC TC 86 and SC 86A dealing with fiber optics.

Ian Davis

davisim@corning.com

Ian Davis is the regional marketing manager for EMEA, responsible for developing and executing optical fiber product strategy within the region. He joined Corning in 1989 and has held various positions in product engineering, product line management, and applications engineering management. Most recently, he was a strategic alliances manager, establishing and maintaining relationships with key suppliers, customers, end-users, and system equipment manufacturers.

Davis received First Class Honors from Nottingham University, graduating with a Bachelor of Science Degree in Physics. He also received a diploma in Management Studies from St. Helens Technical College in Merseyside, England.